

**A CHEMICAL AND BIOLOGICAL
WARFARE THREAT:
USAF WATER SYSTEMS AT RISK**

by

Donald C. Hickman, Major, USAF

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Air War College

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A Chemical and Biological Warfare Threat: USAF Water Systems At Risk

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Contents

	Page
Disclaimer	i
The Author	ii
Acknowledgments	iii
Abstract	iv
I. Introduction	1
II. Taking Water for Granted	3
III. Water System Analysis	7
IV. Chemical and Biological Threats in Drinking Water	13
V. Protecting the Force	25
Appendix: Water System CW/BW Vulnerability Assessment	29
Notes	31

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Abstract

Water and the systems that supply it are national critical infrastructures. Attack to deny or disrupt these systems could have catastrophic effects on the U.S. economy and military power. Water is particularly vulnerable to chemical or biological attack. Not limited to the “traditional” chemical weapons, an adversary has a plethora of cheap, ubiquitous and deadly chemicals on the worldwide market. Using an Internet search and \$10,000, the adversary could build a biological fermentation capability, producing trillions of deadly bacteria that don’t require missiles or bombs for delivery.

The U.S. Air Force water supplies are particularly assailable by asymmetric attack. Institutional myopia renders water system vulnerability assessments disjointed and ineffective. Understanding this vulnerability requires systemic analysis. Probing notional water systems, this study identifies critical points, which if vulnerable could be targeted with chemical or biological weapons to functionally kill or neutralize USAF operations. Though water attacks are historically common, USAF conventional wisdom and official policy center on aerial chemical or biological attack. This study conclusively demonstrates the efficacy of chemical and biological weapons in drinking water. The author proposes four thrusts to improve force protection: comprehensive threat and risk assessment, focused water system vulnerability assessments, re-evaluation of the CW/BW conventional wisdom, and a review of Civil Engineering water system outsourcing and management practices.

A Chemical and Biological Warfare Threat: USAF Water Systems at Risk

Donald C. Hickman

I. Introduction

In late September 1990, during Operation DESERT SHIELD, a RIVET JOINT mission was scrubbed and ABCCC was knocked to 50 percent combat effectiveness for a week. Surveillance coverage was lost, seriously degrading the mission. The aircrews were laid up in bed, the result of unintentional food and water poisoning.

—Major Mike Linschoten

Electronic Combat (EC) Coordinator, CENTAF EC Cell

Future adversaries seeking asymmetric advantage¹ will necessarily identify and attempt to exploit vulnerable U.S. Air Force (USAF) centers of gravity (COG).² Drinking water is one such COG. Given that most if not all airmen (both operational and support personnel) drink water every day, an adversary could functionally destroy or disrupt USAF operations by injecting deadly chemicals or insidious infective agents into an air base water supply. This study addresses how an adversary might target water systems and with what chemical and biological weapons (CW/BW).³ The USAF needs to “check-six” before an adversary cuts its Achilles’ Heel, grounding global engagement before “heels are in the well.”

Humans can live only minutes without air, perhaps several days without water and weeks without food. Yet, who deliberately forgoes water for even a day? It’s axiomatic that in the course of everyday life all humans drink water. Americans in general take clean, potable water for granted because U.S. water systems produce some of the safest water in the world. Cholera, dysentery and other deadly waterborne epidemics are nightmares of the distant past, now relegated to the nightly news and the Third World. Or are they? Though the DESERT SHIELD RIVET JOINT and ABCCC aircrews and missions eventually recovered, had a saboteur laced the water with anthrax spore or sodium cyanide the results could have been catastrophic.

The study assumes the existence of adversaries (transnational or domestic terrorists and/or rogue states) who have the will to attack water supplies with CW/BW and the ability to produce or acquire sufficient

quantities of a particular CW/BW agent. Base personnel are assumed to drink 2 to 15 liters per day (L/d), with the average drink being 0.25 liters. Mature theater air base water systems are assumed to generally conform to standard design criteria as outlined in Military Handbook 1164, *Operation and Maintenance of Water Supply Systems*.⁴ Bare base water systems in immature theaters are assumed to conform with Air Force Manual (AFM) 10-222, Volume 1, *Guide to Bare Base Development*.⁵ Water monitoring is assumed to be routine compliance sampling as required by Air Force Instruction (AFI) 48-119, *Medical Service Environmental Quality Programs*.⁶ This study references sources that identify biological and chemical agents and materials that are known to or presumably can cause acute illness or death from drinking water.

The analyses and findings are organized into three parts, followed by conclusions and a series of force protection recommendations. First, current USAF policy and conventional wisdom regarding water system vulnerability assessments and CW/BW attack are assessed. Though common in history, such attacks are largely ignored in official USAF policies and instructions, leaving operations potentially vulnerable. Next, to determine water system vulnerabilities, notional water systems are analyzed to identify common critical points (targets). Finally, the potential adversary's chemical and biological arsenals are examined. Various chemical weapon agents, industrial chemicals, pathogens and biological toxins are shown to be effective (cause incapacitating illness or death) from drinking water. Finally, this study concludes that if adversaries have access to certain chemical or biological weapons, and to the critical components of a base's water system, they may be able to cripple USAF operations. A series of recommendations are offered to focus attention on this significant force protection issue.

II. Taking Water for Granted

What we think we know can be misleading. Dangerously so.

—Dr. Brad Roberts, Institute for Defense Analysis,
in reference to weapons of mass destruction—

As the sole superpower, the United States is unlikely to be significantly challenged or defeated by conventional military means in the near future. Ironically, this superiority increases the likelihood of asymmetric attack against the U.S. and its fielded forces, as adversaries logically seek to exploit U.S. weaknesses.⁷ One such weakness is water. President Clinton targeted the risk in *A National Security Strategy for a New Century*:

Our **military power** and national economy are increasingly reliant upon interdependent critical infrastructures—the physical and information systems essential to the operations of the economy and government. They include telecommunications, energy, banking and finance, transportation, **water systems** and emergency services. . . . If we do not implement adequate protective measures, attacks on our critical infrastructures . . . might be capable of significantly harming our military power and economy.⁸ (emphasis added by the author)

Depending on objectives, an adversary could attack water in two ways. Physical or cyber attack on the system or its controls could deny water, degrading emergency services and organic community activity. Examples include destruction of dams, pumping stations, and distribution lines. To kill or disable humans, however, the adversary could deliberately contaminate the water with chemicals, biological pathogens or other toxins.

The President's Critical Infrastructure Assurance Office (CIAO) bluntly assessed the risk in *Preliminary Research and Development Roadmap for Protecting and Assuring Critical National Infrastructures*:

In general, vulnerability or risk evaluations that involve biological or chemical attacks by terrorists have not been performed for U.S. water-supply systems. However, a limited number of systems have been evaluated on behalf of the Commission. The results of these analyses indicated that most water supply systems are vulnerable to terrorist attack through the distribution network.⁹

In the author's opinion and experience, the USAF would fare no better. Air Force vulnerability assessment guidance and practice isn't consistent among the various responsible agencies (Security Forces (SF), Bioenvironmental Engineering (BEE), and Civil Engineering (CE)). A disconnect exists between vulnerability assessments done by anti-terrorism experts (typically the SF and the USAF Office of Special Investigations (AFOSI)) and those done by water system experts in Bioenvironmental Engineering and Civil Engineering. The USAF Force Protection Battlelab agrees, summing up the situation like this:

[There is] No well institutionalized USAF process which addresses *intentional contamination* of food or water, especially from asymmetric attack. This vulnerability points out the need for assessing our food and water handling processes, . . .¹⁰

The SF and AFOSI naturally focus on protection from physical attack (see AFI 31-210, *The Air Force Anti-Terrorism (AT) Program*).¹¹ In the author's experience, vulnerability assessments conducted per this AFI are broad based installation assessments, and do not focus on the particular CW/BW threats and risk to water systems critical points. Additionally, the assessment teams rarely include a water system expert or a person versed in the water threats posed by CW/BW, such as one assigned to U.S. Air Force Bioenvironmental Engineering (BEE).

Per USAF policy the BEE is responsible for assessing water system vulnerability. Assessments are governed by AFI 48-119, *Medical Service Environmental Quality Programs*,¹² and AFI 41-106, *Medical Readiness Planning and Training*.¹³ At fixed installations the BEE assesses as required by the various federal or state drinking water regulations, focusing on natural/unintentional contamination. These vulnerability assessments generally don't address deliberate contamination nor are they coordinated with AFI 31-210 assessments. There are no deployed location standards, though the 1991 Armstrong Laboratory report, *Water Vulnerability Assessments*, is a starting point and is used by some in the field.¹⁴

The civil engineers operate and maintain USAF water systems and are the commander's principal advisors on CW/BW issues. Arguably, one would expect to find water system vulnerability assessment guidance in CE policy and instruction. The only significant discussion of deliberate waterborne risk is found in the field guide Air Force Handbook 10-222, *Guide to Civil Engineer Force Protection*.¹⁵ This handbook recognizes the possibility that CW/BW attacks in a deployed environment can be

waterborne and provides a checklist of preventive measures. The primary CE contingency planning tool is the “Contingency Response Plan (CRP).”¹⁶ Annex P, “Main Water Supply and Distribution System,” and Annex Q, “Alternate or Emergency Water Supply,” to the Contingency Response Plan should address the threats, impacts and risks of deliberate CW/BW attack.¹⁷ In the author’s experience as a MAJCOM evaluator, these annexes rarely address this contingency.

Perhaps the vulnerability assessment disconnect is the result of institutional myopia about the CW/BW risk to water systems. Air Force conventional wisdom focuses on aerial CW/BW attacks, omitting chemical threats to water and downplaying biological attacks as highly unlikely. Indeed, the Air Intelligence Agency report, *Worldwide Chemical-Biological Threat to USAF Air Bases: 1995-2005 (U)*,¹⁸ and USAF nuclear, biological and chemical (NBC) defense guidance (Air Force Manual (AFM) 32-4017, *Civil Engineer Readiness Technician’s Manual for Nuclear, Biological and Chemical Defense*),¹⁹ presume that CW/BW will be delivered by air (artillery, missiles, aircraft sprayers, etc.) against airmen, airfields and airplanes. Conventional wisdom also holds that any CW/BW risk to military water is from collateral (secondary) contamination of surface supplies.²⁰ In this view, dilution and degradation in the air and water reduce weapon effectiveness. Additionally, since aerial attacks raise alarms, water contamination will be suspect and the water will be tested subsequently and treated prior to any consumption.

There is no dispute that aerial CW/BW attack could ground USAF operations, and it must not be discounted. However, downplaying the possibility and probability of water system attacks compromises USAF operational preparedness. In 20 pages of NBC hazard checklists, Air Force Manual (AFM) 32-4017 mentions water only twice, and not in terms of CW/BW threats (“Are there adequate supplies for drinking?” and “Do adequate supplies exist for contamination control and fire fighting activities?”).²¹ AFM 32-4017 leaves little doubt about the perceived risk of waterborne attack:

This method of delivery [water contamination] is probably of little threat to modern military and civilian populations because of advanced water treatment facilities. However, it may be a significant threat to less developed nations.²²

Information provided to senior leadership also downplays the waterborne risk. For example, even though Air Force Pamphlet 32-4019,

Chemical- Biological Warfare Commander's Guide, recognizes covert operations have increased the potential for biological contamination of food and water supplies; nonetheless, when addressing protection, it makes no mention of securing water systems.²³ Additionally, Air Force Handbook 32-4014, *USAF Operations in a Chemical and Biological (CB) Warfare Environment, Planning and Analysis*, fails to identify water as a significant threat vector, only recommending use of "approved food/water sources" in "low-risk" environments.²⁴ However, this recommendation applies to all USAF operations regardless of CW/BW risk. The handbook offers no real mitigation for water system attacks. The airborne attack dogma has blinded force protection from historical realities.

Deliberate chemical and biological contamination of water supplies is common in history. Attacks have ranged from the crude dumping of human and animal cadavers into water supplies to well orchestrated contamination with anthrax and cholera. Cyanide has been used as a deadly waterborne poison for thousands of years. In ancient Rome, Nero eliminated his enemies with cherry laurel water (cyanide is the chief toxic ingredient).²⁵ In the U.S. Civil War, Confederate soldiers shot and left farm animals to rot in ponds during General Sherman's march, compromising the Union water supply.²⁶ During World War II, the Japanese attacked at least 11 Chinese cities, intending to contaminate food and water supplies with anthrax, cholera, and various other bacteria. Hitler's forces also released sewage into a Bohemia reservoir, deliberately sickening the rival population.²⁷ Terrorists are using CW/BW. The Aum Shinrikyo Cult attacked a Tokyo subway with sarin gas in 1995 and they are known to have produced and unsuccessfully attempted to use anthrax and botulism toxin nine times as well. In 1985 the Rajneesh religious cult sickened 750 people in The Dalles, Oregon, by spreading salmonella bacteria on local salad bars.²⁸ In an unprecedented violation of the Geneva Conventions, Yugoslav federal forces, or those allied with them, appear to have poisoned wells throughout Kosovo in October/November 1998. Those responsible dumped animal carcasses and hazardous materials (chemicals like paints, oil, and gasoline) into seventy percent of area wells, deliberately sickening the populace and denying them the use of the wells.²⁹

Despite a history of armies poisoning rival water supplies, USAF institutional dogma downplays the risk of asymmetric CW/BW attack on water. Nationally recognized as critical infrastructures, water systems, including the USAF's, are vulnerable to disabling attacks. At present, the USAF lacks an institutionalized assessment process of this threat. Instead,

various agencies conduct discordant assessments, failing to scrutinize the primary risk of deliberate sabotage using CW/BW in water supplies.

III. Water System Analysis

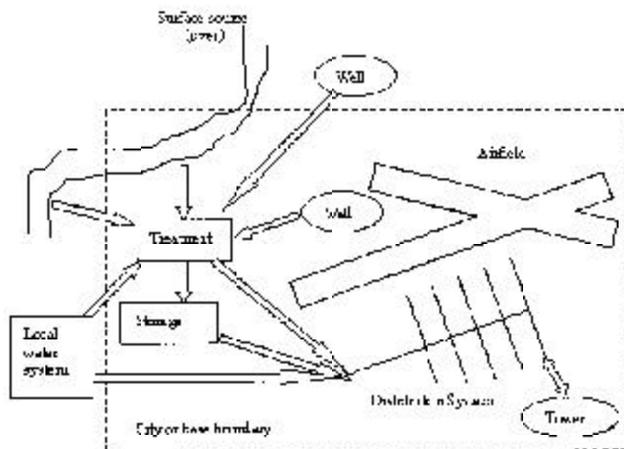
The water supplied to U.S. communities is potentially vulnerable to terrorist attacks by insertion of biological agents, chemical agents, or toxins. . . . The possibility of attack is of considerable concern, . . . these agents could be a threat if they were inserted at critical points in the system; theoretically, they could cause a large number of casualties.

—The President’s Critical Infrastructure Assurance Office

In order to successfully affect operations by water system attack, an adversary would have to dissect the water distribution system to target components vulnerable to attack. Air Force doctrine calls these components “critical points.”³⁰ This section is devoted to coarse analysis of notional³¹ water systems to identify potential critical points. Fixed-base water distribution systems, generally found in mature theaters of operation, are essentially community (city) water systems. Bare base systems are generally found in immature theaters of operations. Analyzing a notional community water system and a bare base (austere) system illuminates potential target sets for CW/BW attack.

Notional Community Water System

A community water system, whether it serves New York City, a summer camp in the Rocky Mountains, or a notional Air Force Base has four basic components.³² As illustrated in Figure 1., “Notional Water Distribution System,” these components are (1) source(s), (2) treatment, (3) storage, and (4) distribution. Arrows indicate water transport and flow direction in this system. Sources include treated water from other local systems, and raw water from deep wells and/or surface sources such as lakes, rivers or the ocean. Raw water is transported to a treatment plant to remove natural or manmade contaminants, ultimately producing drinking water. Drinking water is stored in clear wells or reservoirs and then pumped into the community’s system under pressure. Within the system, pressure is maintained by booster pumps and usually one or more water towers. These towers store water and provide pressure in the system (known as “head”) by



force of gravity. The elevated water in the towers is typically not under pressure.

Figure 1. Notional Water System

Raw water sources usually supply the system's water. Wells and surface sources might be geographically separated by miles from their treatment plants. In many cases they may be off the property boundary of the notional city or airbase. In properly constructed wells, submerged pumps collect water from relatively safe underground aquifers. Outside of the U.S., wells may be simple lined pits. All wells contain a confined volume of raw water that may be suitable for mixing or dissolving introduced CW/BW agents. Water is pumped to the surface, and then, as the arrows indicate, to the treatment system. Accessible wells are vulnerable. If a saboteur can circumvent the well casing, cap or other protection, he can contaminate the well. Because wells provide a potentially vulnerable confined volume from which water is transported directly into the distribution system, they are potential critical points for CW/BW attack.

While less vulnerable than wells, surface sources are also vulnerable critical points. Rivers, lakes and other surface bodies may also supply raw water. Collection systems vary, but essentially they all consist of an intake structure, pumps and pipes. Dilution makes effective contamination of these sources more difficult. The adversary must directly inject into the intake, or otherwise contaminate the source water to the poison's effective concentration in order to disrupt the community water system.

Local system water is the final water supply source. By policy, the USAF is required to use local municipal or regional systems whenever feasible.³³ In this case two systems connect their distribution mains, allowing water transfer from one to the other. Valves usually control these connections, isolating the systems when necessary. As shown in Figure 1., local water might be plumbed directly into the community system, or might be routed through the treatment plant first. In practice, the receiving system usually exercises little control over the operation and maintenance of the producing system. Therefore, since a saboteur could contaminate the receiving system via the local system, the local systems must be considered critical points.

Raw water is treated at the treatment plant to meet federal, state standards, or Department of Defense (for overseas fixed installations) guidelines and to improve its taste and corrosion characteristics. To meet standards, contaminants must be removed or neutralized. Treatment requirements vary greatly depending on raw water quality and community population (these factors affect which standards apply). A small system supplied by a secure well might only require simple chlorination. Larger systems with surface sources have multiple filtration, physical/chemical modification and disinfection units. Common in the U.S., but typically not used in Europe, chlorine disinfectant is added to kill microbial contamination and residual chlorine is maintained to control microbial life within the system. Examples of other chemical addition are precipitation of iron or other metals, reduction of the water's corrosivity and adding fluoride for children. Upon treatment, the water is considered potable or safe to drink.

By its very nature a treatment plant both provides security from and facilitates CW/BW attack. Treatment processes may very well remove/neutralize an agent introduced into the raw water or local system. On the other hand, it is the controlling point for system quality where chemicals are deliberately and systematically added to the water. The plant lends itself as an ideal attack point for water downstream in the system. Therefore, treatment plants are potential critical points of a water distribution system.

After treatment, potable water is either pumped directly into the distribution system or stored in unpressurized clear wells (not a well, but a large, covered storage facility) or other reservoirs. From these the water is then pumped into the system. Clear wells and reservoirs provide disinfectant (typically chlorine) contact time and store system water. Unpressurized and typically only passively defended (usually covered, but not always locked), they are a relatively easy target for contamination. By design they provide

contact time and mixing, and directly feed potable water into the distribution system, and therefore are critical points.

Water towers also store system water. Distribution system water is typically pumped up into the tower, which forms a reservoir and provides constant pressure in the system by force of gravity, reducing electric utility costs. Like in the clear wells, these tanks are usually not under pressure. Similarly, they provide a high mixing volume and direct access to the potable water. They are passively defended with fences and gates on the ladders, and by the fact one must climb to the top to gain access. Like clear wells, they are critical points.

Post treatment and/or clear well, the water is pumped into the distribution system. The system is an underground network of iron, concrete or PVC (plastic) pipes that transport the treated water under pressure to the consumers. Ultimately, water is plumbed into each building from these underground mains. High pressure makes it difficult, though not impossible, to inject material into the typically buried lines. A distribution system typically has a variety of valve pits and other control points where maintenance personnel, or an adversary, may gain access to the water. Though relatively secure, the system pipes and valves are critical points.

Notional Austere Water System

The same four basic components make up a notional austere water system.³⁴ Referring again to Figure 1., they are source(s), treatment, storage and distribution. Transportation and storage differentiate the two system types. Trucks and above ground lines usually transport the water, and portable bladders are often used for storage.

Raw water sources face the same vulnerabilities as community systems. Wells may or may not exist, and those that do must be suspect until sanitary evaluations demonstrate their suitability. Third World wells often will not meet U.S. or European construction standards. Passively defended, they are vulnerable to sabotage and therefore are critical points. Surface sources are vulnerable to contamination, but this path is rendered inefficient by resultant dilution of the contaminant. To be effective, a saboteur must either contaminate the entire source to the effective concentration, or inject directly into the intake. Though lower risk than wells, surface sources are critical points.

Transport to treatment will vary, from tanker truck or portable, above ground lines to, in some cases, buried semi-permanent lines. Anytime the water is above ground and/or not under pressure, access is relatively easy,

facilitating sabotage. Treatment is typically reverse osmosis (RO) followed by chlorination. Portable RO units will remove nearly all suspended particulate (including biological matter) and many chemical contaminants. Again, treatment is a dual-edged sword. On the one hand it can provide protection from contaminants introduced at the source. But, in the wrong hands, it is a direct vector into the system's "potable" water. Therefore, bare base treatment is also a critical point.

Post treatment, water is typically pumped into unpressurized storage bladders. These bladders function as storage reservoirs. They suffer the same vulnerabilities (unpressurized, passive defense if any, long contact time, and feed the distribution systems) and therefore make inviting sabotage targets. Distribution of the water varies with the local conditions. Notionally, from the storage bladders it is trucked or piped to other bladders, and eventually distributed to the ultimate consumer. This might be from sinks and taps or from portable water buffaloes. In most cases the water isn't under high pressure and is only passively defended. Distribution at bare bases must be considered a critical point.

In conclusion, water is an airbase center of gravity. The proceeding analyses of notional community and austere water systems reveals "critical points." These points provide potential targets for asymmetric CW/BW attacks. Wells, surface sources and local systems can be contaminated. Treatment operations are dual-edged, removing contaminants but also providing direct system access. Storage structures are ideal contamination points. Distribution networks may provide system access for potential adversaries.

IV. Chemical and Biological Threats in Drinking Water

Any adversary with access to basic chemical, petrochemical, pharmaceutical, biotechnological or related industry can produce chemical or biological weapons.³⁵ Compared to aerial attack (inhalation or skin contact), effective doses are easier to obtain in water (less dilution than air and directly ingested by the target airmen), and in many cases the materials are more stable (protected from ultraviolet and temperature extremes, although exposed to chlorine). To effectively kill or disable from drinking water chemical and biological agents must be:

- 1.-Weaponized, meaning it can be produced and disseminated in large enough quantities to cause desired effect.
- 2.-Water threat, meaning it is infectious or toxic from drinking water.
- 3.-Stable, meaning the agent maintains its structural and virulent effects in water.
- 4.-Chlorine resistance, meaning the agent isn't significantly oxidized by free available chlorine (FAC) present in most American water systems. USAF standard is typically 0.2 parts per million FAC. Chlorine susceptibility can be negated by inactivation of system chlorination devices.³⁶

Chemical weapons in this study are defined as the classic CW agents (nerve, blister, blood, etc.) and various industrial chemicals that could be used as water system poisons. Despite USAF institutional myopia in identifying threats to water attack, technical research by the USAF and Army public health communities has demonstrated the efficacy and effects of chemical or biological attacks on drinking water. These sources provide the majority of information for this section of the report.

Summary of Applicable Studies

There are four major studies of the vulnerability of water supplies to CBW attacks. First, the seminal USAF study of CW/BW threats to water supplies is Major John Garland's Armstrong Laboratory Technical Report, *Water Vulnerability Assessments*, which focuses on water system emergency planning and identifies toxic concentrations of certain materials.³⁷ Second, in another study by experts from the U.S. Army's Center for Health Promotion and Disease Prevention, titled *Natural And Terrorist Threats To*

Drinking Water Supplies, identifies 11 CW/BW materials that are effective in drinking water.³⁸ Third and fourth, the greatest volume of work, however, was by the National Research Council (NRC) and the Lawrence Livermore National Laboratory (LANL). Table 1., “Summary of Chemicals Effective in Drinking Water,” outlines each author’s findings.

The NRC and LANL investigated the effects of CW agents and other chemicals in military (Army) field drinking water. The primary report is LANL’s *Evaluation of Military Field-Water Quality*.³⁹ In it a variety of CW agents and industrial chemicals are evaluated for the potential impact on military field operations. The NRC’s Committee on Toxicology updated LANL’s study with a more current assessment of the effects of specific CW agents in *Guidelines for Chemical Warfare Agents in Military Field Drinking Water*.⁴⁰

The LANL and NRC agree with conventional military CW/BW wisdom. The two reports assume natural or secondary contamination of the water source(s) versus contamination by direct attack or sabotage. The assumed at risk population is the average 70-kilogram soldier who, in field conditions will be drinking from 5 to 15 liters per day. The studies propose guideline contaminant concentrations below which military mission degradation isn’t expected, but don’t identify lethal or incapacitating doses.

The chemicals for which LANL and NRC propose acceptable guidelines are known or are expected to have certain human oral lethal/incapacitating dose levels. Those doses are necessarily greater than the reported acceptable consumption guidelines. Nonetheless, an adversary could conceivably inject sufficient material to generate concentrations well above the guideline acceptable doses, resulting in the death or disablement of all personnel who drank the water, causing major operational disruptions.

Chemical Agents

There are five types of CW agents: 1) nerve agents, 2) blister agents, 3) choking agents, 4) blood agents, and 5) hallucinogens.⁴¹ Many countries (Russia, China, North Korea, Iraq, and Iran for example) are known to possess, and in some cases have used, chemical weapons. The Aum Shinrikyo cult in Japan crossed a terrorist psychological barrier in 1995 when it attacked a Tokyo subway with sarin, a nerve agent.⁴² By design, these agents are most effective as vapor inhalation hazards, either through liquid or vapor contact. As previously discussed, even though their primary designed effects are through inhalation and by dermal exposure a few CW agents are

lethal or incapacitating when placed in drinking water (see Table 1.) and ingested.

Table 1. Summary of Chemicals Effective in Drinking Water

Chemical Agents (milligrams per liter (mg/l) unless otherwise noted)	Acute Concentration ^a	Recommended Guidelines	
		0.5 L	5 L/Day
Chemical Warfare Agents			
Hydrogen cyanide	25	6.0	2.0
Tabun (GA, microgram/liter (μ /l))	50	70.0	22.5
Sarin (GB , μ /l)	50	13.8	4.6
Soman (GD, μ /l)	50	6.0	2.0
VX (μ /l)	50	7.5	2.5
Lewisite (Arsenic fraction)	100-130	80.0	27.0
Sulfur Mustard (μ /l)		140.0	47.0
3-quinuclidinyl benzilate (BZ, μ /l)		7.0	2.3
lysergic acid diethylamide (LSD)	0.050		
Industrial Chemical Poisons			
Cyanides	25	6.0	2.0
Arsenic	100-130	80.0	27.0
Fluoride	3000		
Cadmium	15		
Mercury	75-300		
Dieldrin	5000		
Sodium fluoroacetate ^c		None provided	
Parathion ^c		None provided	

Sources:

a. Major John Garland, *Water Vulnerability Assessments*, (Armstrong Laboratory, AL-TR-1991-0049), April 1991, 8-9. The author assumes acute effects (death or debilitation) after consumption of 0.5 L.

b. National Research Council, Committee on Toxicology, *Guidelines for Chemical Warfare Agents in Military Field Drinking Water*, 1995, 10. Listed doses are "safe."

c. W. Dickinson Burrows, J. A. Valcik and Alan Seitzinger, "Natural and Terrorist Threats to Drinking Water Systems," presented at the American Defense Preparedness Association 23rd Environmental Symposium and Exhibition, 7-10 April 1997, New Orleans, LA, 2. The authors consider the organophosphate nerve agent VX, the two hallucinogens BZ and LSD, sodium cyanide, fluoroacetate and parathion as potential threat agents. They do not provide acute concentrations or lethal doses.

The LANL and NRC reports identify hydrogen cyanide (blood agent), the nerve agents Tabun, Sarin, Soman and VX, the blistering agents Lewisite and sulfur mustard, and the hallucinogen BZ as potential drinking water poisons. Garland focuses on LSD (a hallucinogen), nerve agents (VX is listed

as most toxic), arsenic (Lewisite) and cyanide (hydrogen cyanide). Burrows, et al, list BZ, LSD and VX. These agents, however, are not the only chemicals a saboteur might use in drinking water.

Industrial Chemical Poisons

The world is replete with dangerous industrial chemicals, hazardous materials, pesticides, fungicides, and the like. Many of these are acutely toxic to humans in doses obtainable by deliberate water system contamination. While it's beyond the current scope of this study to exhaustively survey all known chemicals and hazardous materials to determine potential drinking water threats, a summary review by major classes (pesticides and inorganic chemicals) can indicate areas of concern. The LANL report considers general classes of chemicals, while Garland identifies several toxic compounds, and Burrows, et al, list a few specific threat agents.

Pesticides and Related Chemicals. These materials for the most part are designed to kill insects, rodents, fungi, plants, etc., and are produced, distributed and used throughout the world. Organophosphate pesticides, chlorinated pesticides, and rodenticides are particularly toxic and their effects on humans are nearly identical to that of CW nerve agents. Commercial products contain low concentrations of active ingredient, but a determined adversary could easily acquire pure active ingredients in the open or black markets. Malathion, methyl parathion, and chlorpyrifos are chemically very similar to the organophosphate nerve agents, paralyzing an insect's nervous system.⁴³ Organochlorine pesticides, like lindane, dieldrin, methoxychlor and endosulfan, also affect the nervous system. The rodenticides sodium fluoroacetate, strychnine, crimidine, yellow phosphorus, and thallium sulfate can cause incapacitation or death in humans at very small doses.⁴⁴ Burrows, et al, list sodium fluoroacetate and parathion, and Garland lists dieldrin as potential threat agents.

Inorganic Chemicals. These metal salts, acids, and other substances offer a wide variety of options to the potential saboteur. Arsenic and cyanide are strong potential threats according to the LANL report. Garland focuses on cyanide, arsenic, fluoride, cadmium and mercury. Burrows, et al, single

out sodium cyanide. Arsenic, the active agent of Lewisite, is readily available on the open market, is soluble, and lethal in high doses. Cyanide, particularly sodium cyanide, is available on the worldwide open and black markets, is soluble, and certainly is lethal in relatively low doses. Magnesium, a soluble metal, and sulfate (an inorganic anion) can cause diarrhea in high oral doses.

Biological Agents

Similar to CW agents, most biological warfare (BW) agents are developed for aerial dissemination of an aerosolized organism or toxin. However, many lung-targeting BW agents might be effective via the digestive track, and some, *Shigella* spp. and *Vibrio cholerae* for example, are probably solely water-borne threats. In his seminal report, *Biological Warfare Agents as Potable Water Threats*, Jerry A. Valcik, P.E., states:

Most biotoxins [biological agents] would probably be effective threats to drinking water under suitable conditions. For others, however, either there is no known infectious path through ingestion, or the agent cannot survive in water.⁴⁵

There are two types of biological threats, pathogens and toxins. Pathogens are live organisms, such as bacteria, viruses or protozoa, which infect and cause illness and/or death. The other are biological toxins, chemicals derived from organisms, primarily bacteria and fungi, which cause chemical toxicity resulting in illness and/or death.⁴⁶ For less than \$10,000, anyone with gear no more sophisticated than a home brewing kit, protein cultures and personal protection can cultivate trillions of bacteria with relatively little personal risk.⁴⁷

Pathogens

Mankind wages a constant battle against pathogens. Bacteria, viruses, protozoa, nematodes fungi, and others are the causes of most infectious diseases. Living organisms, they require a host population and certain environmental conditions (temperature, humidity/water, and protection from sunlight) for survival. Upon infection, the pathogen must “grow” in the host. This latency period requires time, depending on the organism, from hours to weeks. Therefore, pathogens are:

Table 2. Threat Potential of Pathogens

AGENT	TYPE ¹	WEAPON- IZED	WATER- THREAT	STABLE IN WATER	INFECTIOUS DOSE ²	CHLORINE TOLERANCE ³
Anthrax	B	Yes	Yes	2 yrs spore	6,000	Spores resistant
Brucellosis	B	Yes	Probable	20-72 days	10,000	Unknown
<i>C. Perfringens</i>	B	Probable	Probable	Common in sewage	~500,000	Resistant
Tularemia	B	Yes	Yes	< 90 days	25	Inactivated, 1 ppm, 5 min
Shigellosis	B	Unknown	Yes	2-3 days	10,000	Inactivated, 0.05 ppm, 10min
Cholera	B	Unknown	Yes	“Survives well”	1,000	“Easily killed”
Salmonella	B	Unknown	Yes	8 days, fresh water	10,000	Inactivated
Plague	B	Probable	Yes	16 days	500	Unknown
Q Fever	R	Yes	Possible	Unknown	25	Unknown
Variola	V	Possible	Possible	Unknown	10	Unknown
Hepatitis A	V	Unknown	Yes	Unknown	30	Inactivated, 0.4 ppm, 30 min
Crypto- sporidiosis	P	Unknown	Yes	Stable days or more	130	Oocysts resistant

Source: Jerry A. Valcik, P.E., Medical Issues Information Paper No. IP-31-017, *Biological Warfare Agents as Potable Water Threats*, 2 and Appendices A-T.

Notes:

1. B- bacteria, R- Rickettsia, V-virus, and P-protozoan
2. Infectious dose based on number of organisms or spores for bacteria, number of oocysts for Cryptosporiosis and viral units for virus.
3. Chlorine resistance at FAC concentration of 2.0 parts per million (ppm). Most USAF water systems maintain FAC concentrations of less than 1.5 ppm. Resistance at these levels is unknown. Many overseas bases may have no FAC as the host nation may not chlorinate its water.

best suited for covert, terrorist or non-conventional attack, the types central to this study. Adapted from Valcik’s report, Table 2., “Threat Potential of Pathogens,” lists the drinking water threat potential of pathogens. As indicated, many BW pathogens have the essential characteristics of effective weapons. The bacterial agents in particular show great utility as weapons. Infectious doses range from the miniscule, 25 organisms (Tularemia), to around 500,000 for *C. Perfringens*. Many are stable in water and exhibit chlorine resistance.

Biological Toxins

Biological toxins are chemicals derived from the natural metabolic processes of organisms. From a practical perspective, they more closely resemble chemical threats than biological pathogens. Large scale fermentation of the parent organism and toxin recovery are feasible, particularly for bacteria derived toxins. Some may be synthesized in a laboratory. Many are environmentally stable and water soluble.⁴⁸ Effective doses are extremely small, facilitating sabotage. See Table 3., "Threat Potential of Biological Toxins," which lists drinking water threat potential of known biological toxins.

Table 3. Threat Potential of Biological Toxins

AGENT	WEAPON- IZED	WATER THREAT	STABLE IN WATER	ESTIMATED EFFECTIVE DOSE	CHLORINE TOLERANCE ¹
Botulinum Toxin	Yes	Yes	Stable	0.07 mg	Inactivated, 6 ppm, 20 min
T-2 mycotoxin	Probable	Yes	Stable	None given	Resistant
Aflatoxin	Yes	Yes	Probably stable	2 mg	Probably tolerant
Ricin	Yes	Yes	Unknown	None given	Resistant at 10 ppm
Staph Enterotoxins	Probable	Yes	Probably stable	4 mg	Unknown
Microcystins	Possible	Yes	Probably stable	1 mg	Resistant at 100 ppm
Anatoxin A	Unknown	Probable	Inactivated in days	None given	Unknown
Tetrodotoxin	Possible	Yes	Unknown	1 mg	Inactivated, 50 ppm
Saxitoxin	Possible	Yes	Stable	0.3 mg	Resistant at 10 ppm

Source: Jerry A. Valcik, P.E., *Medical Issues Information Paper No. IP-31-017, Biological Warfare Agents as Potable Water Threats*, 2.

Note: 1. Chlorine resistance at free available chlorine (FAC) concentration of 2.0 parts per million (ppm). Most USAF water systems maintain FAC concentrations of less than 1.5 ppm. Resistance at these levels is unknown. Many overseas bases may have no FAC as the host nation may not chlorinate its water.

Chemical and Biological Monitoring and Detection

Rapid detection and quantification of a CW/BW attack on a water supply is difficult at best. Unlike aerial delivery, a CW/BW attack via water won't be heralded by incoming missiles or bombs and concomitant weapons detonation. Dumping a thermos of concentrated anthrax spores into a clear well won't garner much attention. The first evidence of attack is likely to be a flood of sick or dying at the emergency room. By the time water is recognized as the source, identification and quantification of the agent could take days if not weeks. To further complicate force protection, the adversary could tailor the effect based on his objective, using chemicals or fast acting pathogens for a quick kill, or slower incubating pathogens for delayed effects.

Two operational constraints cause this situation. First, there is currently no real-time detection capability for BW pathogens in water, and only a limited capability for chemicals. The Bioenvironmental Engineering Flight (BEF), a component of each base's Aerospace Medicine Squadron, normally conducts both fixed-base and bare-base water sampling. The BEF typically operates a coliform bacteria⁴⁹ analytical laboratory while centralized military or contract laboratories perform the vast majority of chemical analyses (the BEF uses field kits to analyze chlorine residual and hydrogen ion concentration (pH)). Unfortunately, a coliform analysis does not detect any of the pathogens listed in Table 2. Microbiological analyses for BW pathogens, from collection to reporting results, can vary from a day to weeks, depending on transportation logistics and analytical complexity. If the pathogen is in a spore or cyst form, it may be extremely difficult to identify and enumerate. Turn-around times for chemical samples can take just as long.

Certain deployable BEF units might maintain the M272 Chemical Agent Monitor Water (CAMW) kits and/or chemical test strips for cyanide and arsenic. However, these kits are not maintained by all units or at all bases. In addition to war reserve materiel, some BEF may own and operate a direct-reading chemical spectrophotometer, which may be able to detect a limited number of inorganic chemicals. The BEF has no in-house capability to detect or monitor organic chemicals and pesticides. The USAF and Army are developing the Joint Chemical/Biological Agent Water Monitor (JCBAWM) with a prototype due in the field in 2001.

The second operational constraint is sampling frequency. Fixed-base routine water sampling is conducted to meet certain national public health

standards in accordance with AFI 48-119, *AF Medical Service Environmental Quality Programs*,⁵⁰ the various state drinking water regulations, and the various Environmental Final Governing Standards (for overseas bases.) These are public health standards, designed for the detection of some acute contaminants (coliform bacteria and nitrate for protection of infants) and a variety of chronic contaminants (pesticides, heavy metals, etc.). Monitoring schedules range from weekly checks for coliform bacteria to every three years for many other chemicals. The USAF has no deployed or bare-base standards, and sampling is based on risk assessment and logistical constraints. The Civil Engineers, as operators of the water distribution system, typically sample chlorine residual and pH at the treatment plant. Frequency of tests varies greatly depending on manpower and system operational requirements. Even if the USAF had the detection capability, under current policy and manning the odds are good that an attack would not occur on a sampling day.

Notional Examples of Disabling Attack

Botulism Toxin

Assuming adversaries could produce or acquire Botulinium Toxin, how much material is needed to effectively poison a person with 0.25 liter of water? Botulinium Toxin's effective dose is 0.07 mg, it is stable in water, and it is resistant to chlorine at the normal level of 1.0 ppm (see Table 3.). Assuming the notional community water system has a clear well with a 200,000-gallon volume (750,000 liters, typical of a medium-sized system), and perfect mixing and solubility, just 0.21 kilograms (kg, equal to 0.46 pounds, less than a cup of water) could generate a disabling dose.⁵¹ As the water entered the distribution system, unsuspecting and unprotected personnel would consume the water, thereby functionally killing such USAF global engagement operations in that region.

Sodium Cyanide

Sodium cyanide (NaCN) presents a special challenge to USAF force protection because it is in plentiful supply in the mining and metals technology industries. An Internet search for "sodium cyanide" reveals a plethora of suppliers throughout the world. It is an odorless white salt, which is stable and highly soluble in water (around 80 percent at 35°C). Death or incapacitation can result from a 25 mg oral dose (refer to Table 1.). Cyanide

exerts its lethal effect by stopping cell aerobic metabolism, thereby suffocating the body's cells.⁵² To generate 25 milligrams in the first quarter liter (about a cup) a person drank would require that 188 kg (415 pounds) of NaCN be dumped into a 200,000 gallon clear well or water similar reservoir.⁵³

Thus, a saboteur with four and a quarter 100-pound "cement" bags of NaCN, with access to the clear wells, or storage bladders in the austere case, could generate a poisonous slug of water that could kill or incapacitate every consumer downstream. Properly timed, a "construction worker" could cripple operations through a relatively cheap and simple asymmetric attack.

Cholera

Cholera is an acute intestinal disease in man, caused by the bacterium *Vibrio cholerae*. Symptoms include profuse watery diarrhea, rapid dehydration, and a state of collapse. Treatment consists of replacement of fluid and electrolytes; untreated, the victim may die within hours after onset.⁵⁴ This disease is responsible for mass epidemics when basic sanitation and water supply break down. It is inactivated by chlorine.

How might the saboteur proceed this time? What if the notional treatment plant wasn't manned 24-hours per day and didn't remotely and continuously control chlorine levels? At the end of a work shift, a saboteur might shut off the chlorinator, and several hours later start dumping cultured *V. cholerae* into the clear well, or maybe into a water tower. Within hours of consumption, profuse diarrhea would disable all consumers. An attack at a austere location could severely strain health care resources. Left untreated, many could die. Properly timed, the resultant epidemic could paralyze on-scene operations.

In summary, potential adversaries have a veritable supermarket menu of weapon choices. Chemical warfare agents, such as hydrogen cyanide, Lewisite, or VX could be used to poison water. Many industrial chemicals and pesticides are close chemical cousins to the usual CW agents. These materials are readily available in the world market, and, when concentrated and employed in water, can produce lethal or incapacitating doses. Many pathogens and biological toxins are water-borne threats. An adversary could turn these age-old enemies on a friendly water system for devastating, system-wide effects. The USAF isn't currently equipped to sample and

analyze most CW/BW water threats, and monitoring programs are managed for peacetime compliance instead of the detection of deliberate attack. A thermos full of Botulinium Toxin or concentrated *Vibrio cholerae* is nearly impossible to detect and intercept as it crosses base boundaries. The problem is even harder to prevent if the base supply shares an offbase water supply with the local regional community. Once dumped into the water supply, the first evidence of such an attack will likely be casualties at the clinic. For less than \$10,000 an adversary could wage an unsophisticated asymmetric attack, perhaps delivering a knockout blow to unprepared and unsuspecting USAF units dependent on those water supplies.

V. Protecting the Force

In a world of sophisticated and expensive weapon systems, base defense is not a glamorous mission and is therefore not given the priority it requires.

—Lt Col Michael Wheeler
The Reality of Air Base Defense—

Clearly, USAF operations could be severely degraded by CW/BW attacks on an air base water system or by attacks on a community water supply that the air base is dependent upon. A center of gravity, drinking water is essential to the airmen who operate and support USAF weapon systems. It is collected, treated, stored, and delivered in systems with common critical points. These points, if vulnerable, are potential CW/BW targets. A terrorist bent on killing Americans, or a rogue nation seeking asymmetric advantage in a pre-emptive strike, has available a plethora of CW/BW agents and materials that are effective in drinking water. Rhetorically, why use ballistic missiles when a thermos laced with cholera or botulism toxin, or a couple of bags of “cement” (sodium cyanide), could functionally destroy operations?

As these examples demonstrated, chemicals, pathogens and toxins are cheap, ubiquitous, and deadly in water. Very little material is needed to inflict lethal or incapacitating doses in an unsuspecting and unprepared population. Adversaries seeking asymmetric advantage could focus on the water attack scenario, severing the USAF’s proverbial “Achilles’ Heel,” grounding operations before “wheels are in the well.”

Though plainly delineated as a security threat at the national level, the USAF institutionally fails to recognize water system risk resulting in a disjointed vulnerability assessment process. Civil Engineering contingency planning inadequately addresses the threats, risks and impacts of deliberate CW/BW attack. Bioenvironmental Engineering vulnerability assessments have traditionally focused on ambient pollution and operational condition risks, not deliberate contamination. Civil Engineering contingency plans and BEE water system vulnerability assessments are rarely rolled into SF and AFOSI installation vulnerability assessments.

Official CW/BW policy and threat assessments focus on airborne CW/BW attack. Any water impact is assumed to be secondary contamination of surface sources. In this scenario, dilution, degradation and targeted treatment render the weapon less effective, resulting in the conclusion that operations are at little risk from waterborne CW/BW attack. The institutional

focus on the threat of adversary missiles and bombs blinds force protection personnel to the CBW water threat. Yet, direct attacks on water systems overcome dilution and some forms of degradation (ultraviolet and temperature extremes), and can circumvent treatment. This study has clearly demonstrated that a variety of traditional CW agents, industrial chemicals, pathogens and biological toxins are potentially deadly weapons when targeted through drinking water. Assuming an adversary could produce or acquire the CW/BW material, delivery could be deceptively easy. It may only be a matter of time before CW/BW attack with a thermos and bolt cutter evolves from the theoretical to reality.

Recommendations

Force protection is a commander's high priority concern. To protect the force, commanders must give higher priority to drinking water vulnerability. Though defense against chemicals and bacteria may not seem immediately relevant to those conducting air operations, the service must "check six" and secure its critical infrastructure. This paper proposes four risk reduction thrusts:

- comprehensive threat and risk assessment;
- focused water system vulnerability assessments;
- re-evaluation of the CW/BW conventional wisdom;
- and a critical review of Civil Engineering water system outsourcing and management practices.

Comprehensive threat and risk assessment starts at the high-threat bases. It is essential that installation commanders in those areas assess their water system critical point security.⁵⁵ A combined team of CE, BEE and SF/AFOSI experts is best suited for this task. Are the passive defenses adequate? Are active defenses dictated? Does the base control who has access to the system's critical points? If the system can't be secured, verifiably safe bottled water should be provided for drinking and cooking. Concurrent with the high threat area assessments, the USAF must embark on a detailed evaluation of the CW/BW threat to its critical water infrastructures, starting with the intelligence community.

This analysis should raise some eyebrows. It posits that an adversary could disable USAF operations with a thermos of bacteria for less than \$10,000. Therefore, it is first recommended that the USAF should bring the assets of the intelligence community to bear on this critical force protection

problem, the potential in various regions of an adversary poisoning USAF unit water supplies. Focusing outside the “aerial delivery against massed troops or airfields” and concomitant secondary source water contamination paradigms, the agents, materials and delivery systems that pose operational threats to water supplies need to be identified and assessed. Building on the cited preventive medicine community’s CW/BW threat, this should also include the threats of physical attack, cyber-attack, and radioactive materials attack. Concurrently, by expanding this study’s critical points analysis, the CE, BEE and civilian water authorities (the Critical Infrastructure Assurance Office and civilian water industry) can focus protection efforts on the highest risk vulnerabilities. Together these data will focus force protection training and vulnerability assessments in the various commands.

The second recommendation is for more focused water vulnerability assessments. This requires BEE and CE integration into the SF/AFOSI vulnerability assessment process. Integrated MAJCOM and/or installation teams, backed by the intelligence assessment of actual water CW/BW vulnerabilities and critical points analysis, can re-evaluate all USAF water systems, including off-base community water systems on which the USAF is dependent, on a prioritized basis. Concurrently, including the detailed CW/BW threat and critical point analysis in Level II and III anti-terrorism training will help raise the general awareness level throughout the USAF.⁵⁶ Threat and risk based assessment of the passive defenses protecting the sources, treatment, storage and distribution system components is critical. In the end, defending priority components from sabotage is likely the most practical counter to CW/CW attack. Offered in Appendix A is a water system CW/BW vulnerability assessment checklist as a starting point for these teams.

Concurrently, real-time detection systems for the most likely and damaging CW/BW attack scenarios might prove to be mission savers. Based on the threat and risk, Civil Engineering as water system managers and Bioenvironmental Engineers as primary samplers should identify detection requirements. The Critical Infrastructure Assurance Office addresses many of these needs in *Preliminary Research and Development Roadmap for Protecting and Assuring Critical National Infrastructures*.⁵⁷ They include rapid and continuous detection of contaminants of concern and enhanced chlorine detection systems. Chlorine could be used as a detection surrogate for contaminants, under the theory that residual chlorine will react with injected CW/BW, necessarily reducing the ambient chlorine concentration.

Unexplained chlorine concentration variations could indicate CW/BW attack.

Third, the USAF can no longer afford to ignore the vulnerability to CW/BW attacks on its water system's critical points. Reducing this vulnerability must be given a top priority in USAF force protection efforts. As discussed, conventional USAF wisdom, reflected in policy and guidance, assumes aerial attack and dissemination of CW/BW. Little attention outside military medical communities has been placed on water system attack. And the majority of those reports assume only secondary contamination of surface water supplies. The Civil Engineering readiness community, as those with the primary responsibility (OPR) for NBC readiness and training, can rectify this by incorporating the intelligence community's threat and risk assessments into official policy and training guidance. Concurrently, the Bioenvironmental Engineering NBC reconnaissance teams must update their training regimens.

Fourth, a final recommendation is that there be a critical review of USAF water system management practices. Civil Engineering has outsourced or privatized many water system functions. This could seriously impact mission security and operational readiness. Has the USAF placed its people and mission at risk in the effort to save money? If USAF water systems in a region have critical vulnerable points, and a successful CW/BW attack could cripple such USAF operations, shouldn't the USAF be concerned about who's running the show? Should military, civil service or contract personnel undergo special security or reliability checks periodically when working with the water systems? What about overseas, where the host nation may control the sources and distribution of water? These force protection concerns demand a bottom-up review of the CE outsourcing program with respect to the risk and threats of CW/BW weapons in drinking water.

In conclusion, water is as crucial to sustaining USAF operations as are combat aircraft, fuel, and munitions. High priority water supplies must be protected to keep the USAF flying, fighting, and winning.

Appendix A

Water System CW/BW Vulnerability Assessment A Check List of Key Questions to Ask

COLLECTION

Wells

- Are the wells covered, preferably in permanent, secured structures?
- Are the wells head covered and locked?
- Are the wells with vents not easily accessible?
- Is the area fenced, well lit, in areas clear of vegetation and obstacles?

Surface Sources

- Are their intakes accessible? If so, can their vulnerability be reduced?

Local supplies

- Who operates and maintains them?
- Are there controlling valves between the system? Who controls them?
- Do they have an adequate vulnerability reduction program?

Alternate emergency sources identified

- Is bottled water available? Does it meet preventive medicine standards?
- Is there an adequate supply? Is it secure?

TREATMENT

How is water disinfected? Is chlorine used?

Are chlorine levels checked throughout the system, by whom, and how often?

What other chemicals are added? How and by whom is the process and the concentration monitored?

Could treatment process(es) be modified to inject unwanted material to prevent this?

Is the facility secured, is it monitored, how often?

Are the grounds fenced, locked, with an area clear of vegetation and obstacles, and is it well lit?

STORAGE (Clear wells, reservoirs, water towers, bladders, etc.)

Is the structure covered, fenced, locked, well lit, with an area clear of vegetation and obstacles?

Can it be isolated from the system?

Are manholes/access ports and vents locked and secured?

DISTRIBUTION

Is the system above ground or below ground? Can it be tampered with?

Are there valve pits on the system? Are the facilities fenced, locked, and secured? Who has access to it?

Are pits located upstream from mission critical facilities?

PERSONNEL

Who has access to any components of the water system?

Are such personnel reliable? Have they been checked out?

How are keys and combination locks secured and managed?

SECURITY PATROLS

Are they regularly conducted? If so, how often and on what sites? Is this sufficient?

Is there remote monitoring of critical points and/or processes? Is it necessary?

SAMPLING/DETECTION

How often are chlorine residual measurements done and where?

Based on local CW/BW threats, what CBW detection capability exists? Are there adequate contingency plans?

Can the medical facility identify and track a waterborne epidemic?

What is the lag time between the first reported case and recognition of a CBW attack?

Notes

1. Air Force Doctrine Document (AFDD) 2, *Organization and Employment of Aerospace Power*, 28 September 1998, 8. “Asymmetric warfare pits our strengths against the adversary’s weaknesses and maximizes our capabilities while minimizing those of our enemy to achieve rapid, decisive effects.” AFDD 2 is referring to U.S. or USAF strengths against an enemy’s weaknesses. Obviously the tables can be turned, and rational adversaries will consider attacking U.S. weaknesses with their strengths.

2. AFDD 1, *Air Force Basic Doctrine*, September 1997, 79. “Those characteristics, capabilities or localities from which a military force derives its freedom of action, physical strength, or will to fight.”

3. In this study chemical and biological warfare agents are defined as chemical agents or industrial chemicals used as weapons in water, and biological warfare agents are pathogens or biological toxins used as weapons. These are a subset of the term “weapons of mass destruction,” which also include nuclear weapons.

4. Military Handbook 1164, *Operation and Maintenance of Water Supply Systems*, 3 March 1997. This document supersedes Air Force Regulation 91-26 (same title) and is the standard for all military fixed installation water systems worldwide.

5. Air Force Handbook (AFH) 10-222, *Guide to Base Development*, vol. 1, 1 July 1996.

6. Air Force Instruction (AFI) 48-119, *Medical Service Environmental Quality Programs*, 25 July, 1994, 7. This document defines drinking water sampling responsibility at all fixed installations worldwide. Actual contaminant limits and sampling frequencies vary depending on applicable state law or country-specific environmental final governing standards (overseas). There are no contingency site sampling requirements.

7. President William J. Clinton, *A National Security Strategy for a New Century* (The White House: October 1998), 19.

8. *Ibid.*, 20.

9. Transition Office of the President’s Commission on Critical Infrastructure Protection and the President’s Critical Infrastructure Assurance Office, *Preliminary Research and Development Roadmap for Protecting and Assuring Critical National Infrastructures*, July 1998, E-3 û E-4; on-line, Internet, 26 January 1999, available from <http://cia.gov/roadmap-e.pdf>.

10. Lt Col Patricia Merrill, Briefing, USAF Force Protection Battlelab, subject: “USAF Force Protection Battle Lab Food and Water Counter Terrorism Initiative,” undated.

11. AFI 31-210, *The Air Force Anti-Terrorism (AT) Program*, 1 July 1997.

12. AFI 48-119, 7.

13. AFI 41-106, *Medical Readiness Planning and Training*, 14 February 1994, 8.

14. Major John Garland, *Water Vulnerability Assessments*, AL-TR-1991-0049 (Armstrong Laboratory, Brooks AFB, Tex.: Air Force Systems Command, April 1991).

15. AFH 10-222, *Guide to Civil Engineer Force Protection*, vol. 3, 1 June 1997, 76.

16. AFI 10-211, *Civil Engineer Contingency Response Planning*, 30 March 1994.

17. *Ibid.*, 14.

18. *Worldwide Chemical-Biological Threat to USAF Air Bases: 1995-2005 (U)*, vol. 1: Executive Summary (U), NAIC-2660F-432-95U, (National Air Intelligence Center), 15 May 95, 3-6.

19. AFM 32-4017, *Civil Engineer Readiness Technician's Manual for Nuclear, Biological and Chemical Defense*, 1 June 1998, 8-13, 198-199, and 220-224. While it focuses on aerial delivery, the AFM recognizes the possibility of waterborne biological attack.

20. National Research Council, Committee on Toxicology, *Guidelines for Chemical Warfare Agents in Military Field Drinking Water* (Washington DC: National Academy Press, 1995), 1-2.

21. *Ibid.*, 232-251. Page 239 has the two water related checklist items. At no point is the CE readiness technician tasked to evaluate risk to water by CW/BW attack.

22. *Ibid.*, 222.

23. Air Force Pamphlet (AFP) 32-4019, *Chemical-Biological Warfare Commander's Guide*, 1 April 1998, 4-13.

24. AFH 32-4014, *USAF Operations in a Chemical and Biological (CB) Warfare Environment, Planning and Analysis*, vol. 1, 1 March 1998, 6-7.

25. Frederick R. Sidell, Ernest T. Takafuji, and David R. Franz, *Medical Aspects of Chemical and Biological Warfare* (Washington DC: Borden Institute, 1997), 273.

26. *Ibid.*, 416.

27. Lt Col George W. Christopher et al., "Biological Warfare: A Historical Perspective," *Journal of the American Medical Association* 278, no. 5 (August 6, 1997), 413.

28. Leonard A. Cole, "The Specter of Biological Weapons," *Scientific American* 275, no. 6 (December 1996), 62. See also, Anthony Fainberg, "Debating Policy Priorities and Implications," chapter in Brad Roberts, editor, *Terrorism With Chemical and Biological Weapons: Calibrating Risks and Responses* (Alexandria, VA: Chemical and Biological Arms Control Institute, 1997), 79.

29. Jeffrey R. Smith, "Poisoned Wells Plague Towns all over Kosovo," *The Washington Post*, n.p.; on-line, Internet, 9 December 1998, available from <http://ebird.dtic.mil/Dec1998/e19981209poisoned>.

30. AFDD 2, 5.
31. Theoretical water systems are evaluated as security concerns preclude consideration of actual systems.
32. Military Handbook 1164, 33-34.
33. Air Force Instruction 32-1067, *Water Systems*, 25 March 1994, 1.
34. Air Force Handbook 10-222, 37-40 and 89-92.
35. AFM 32-4017, 25.
36. Jerry A. Valcik, P.E., Acting Program Director Water Quality, U.S. Army Center for Health Promotion and Preventive Medicine, memorandum to Commander, U.S. Army Combined Arms Support Command, subject: Medical Issues Information Paper No. IP-31-017, Biological Warfare Agents as Potable Water Threats, 24 March 1998. Valcik describes biological weapons in terms of these characteristics. In the opinion of this research paper's author, they stand as well for chemical weapons.
37. Major John Garland, *Water Vulnerability Assessments*, AL-TR-1991-0049 (Armstrong Laboratory, Brooks AFB, Tex.: Air Force Systems Command, April 1991).
38. W. Dickinson Burrows, J. A. Valcik and Alan Seitzinger, "Natural And Terrorist Threats To Drinking Water Supplies" (paper presented at the American Defense Preparedness Association 23rd Environmental Symposium and Exhibition, 7-10 April 1997, New Orleans, La.)
39. J. I. Daniels and G. M. Gallegos, editors, *Evaluation of Military Field-Water Quality*, UCRL-21008 (Livermore, Calif.: Lawrence Livermore National Laboratory, May 1990.)
40. National Research Council, Committee on Toxicology, 3.
41. AFM 32-4017, 166. This AFM identifies nerve, blister, choking and blood agents. The author includes hallucinogens as a fifth type of CW agent.
42. *Ibid.*, 24.
43. "Publication 1933," Mississippi State University Extension Service, n.p.; on-line, Internet, 26 January 1999, available from <http://ext.msstate.edu/pubs/pub1933.htm>.
44. Donald P. Morgan, M.D., Ph.D., "Iowa Pesticide Hazard Assessment Project," n.p.; on line, Internet, 26 January 1999, available from <http://hammock.ifas.ufl.edu/txt/fairs/15193>.
45. Jerry A. Valcik, P.E., Acting Program Director Water Quality, U.S. Army Center for Health Promotion and Preventive Medicine, memorandum to Commander, U.S. Army Combined Arms Support Command, subject: Medical Issues Information Paper No. IP-31-017, "Biological Warfare Agents as Potable Water Threats," 24 March 1998, 1.
46. AFM 32-4017, 221.

47. Leonard A. Cole, "The Specter of Biological Weapons," *Scientific American* 275, no. 6 (December 1996): 61.

48. *Ibid.*, 221-223.

49. Many human diseases are spread through fecally-contaminated water. Specific isolation and examination of many of these pathogens is time-consuming and potentially hazardous. Indicator organisms, the *Coliform* group of bacteria, are used as surrogates.

50. AFI 48-119, 7.

51. Calculated using the following equation: $(0.07\text{mg}/0.25\text{L}) \times (750,000\text{L}) \times (1\text{Kg}/1,000,000\text{ mg}) = 0.21\text{ Kg}$. $0.21\text{ Kg} \times 2.2\text{pound}/\text{Kg} = 0.46\text{ pounds}$. This and the following examples are worst case scenarios, assuming that the contaminated water would enter the system as a slug with uniform concentration. In reality, at the margins the concentration would slowly decrease as it was diluted by water already in the system. However, the effective dose will be maintained for sometime within the system. To overcome dilution, the adversary could model the system flow, and add sufficient additional toxin to achieve the desired concentration at specific points in the system.

52. Sidell et al., 274.

53. Calculated using the following equation: $(25\text{mg}/0.25\text{L}) \times (750,000\text{L}) \times (1\text{Kg}/1,000,000\text{ mg}) \times (49\text{ (atomic mass NaCN)}/26\text{ (atomic mass CN)}) (1/0.75\text{ (assume 75\% soluble)}) = 188\text{ Kg}$. $188\text{ Kg} \times 2.2\text{pound}/\text{Kg} = 415\text{ pounds}$. Assume perfect mixing.

54. Jerry A. Valcik, P.E., Acting Program Director Water Quality, U.S. Army Center for Health Promotion and Preventive Medicine, memorandum to Commander, U.S. Army Combined Arms Support Command, subject: Medical Issues Information Paper No. IP-31-018, Biological Warfare Agents in Drinking Water: Guide for Field Personnel, 24 November 1998.

55. Air Force Instruction 31-210, *The Air Force Anti-Terrorism (AT) Program*, 1 July 1997, 3. Installation commanders are responsible for vulnerability assessments.

56. *Ibid.*, 7.

57. Transition Office of the President's Commission on Critical Infrastructure Protection and the President's Critical Infrastructure Assurance Office, *Preliminary Research and Development Roadmap for Protecting and Assuring Critical National Infrastructures*, E-10, July 1998; on-line, Internet, January 26, 1999, available from <http://ciao.gov/roadmap-e.pdf>.

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